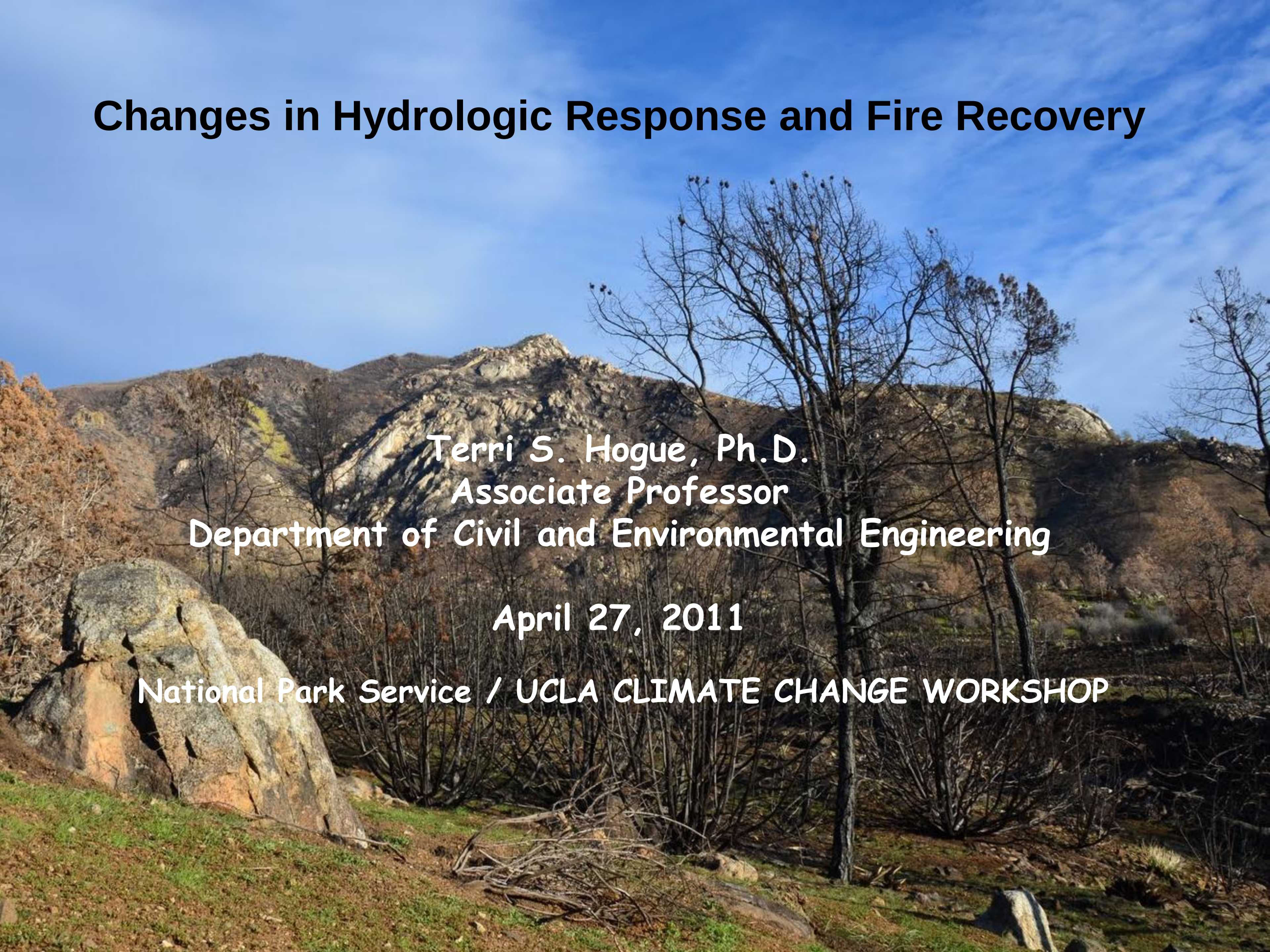


Changes in Hydrologic Response and Fire Recovery

Terri S. Hogue, Ph.D.
Associate Professor
Department of Civil and Environmental Engineering

April 27, 2011

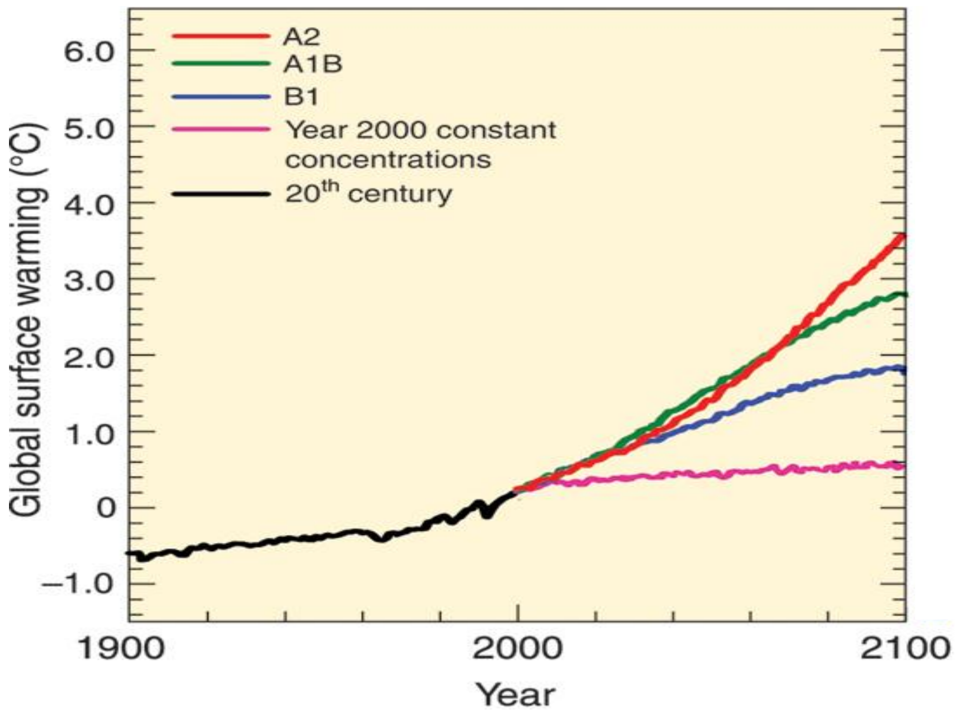
National Park Service / UCLA CLIMATE CHANGE WORKSHOP

Watershed Studies in Southern California

- How will climate change affect regional watershed behavio?
- How will these altered fluxes (water, sediments) impact downstream ecosystems?
- How are watersheds responding to fire (and how will future climate variability alter recovery)?
- How will land cover conversion (urbanization) play a role in future watershed response?
- Will we be able to capture potential change with our current infrastructure?

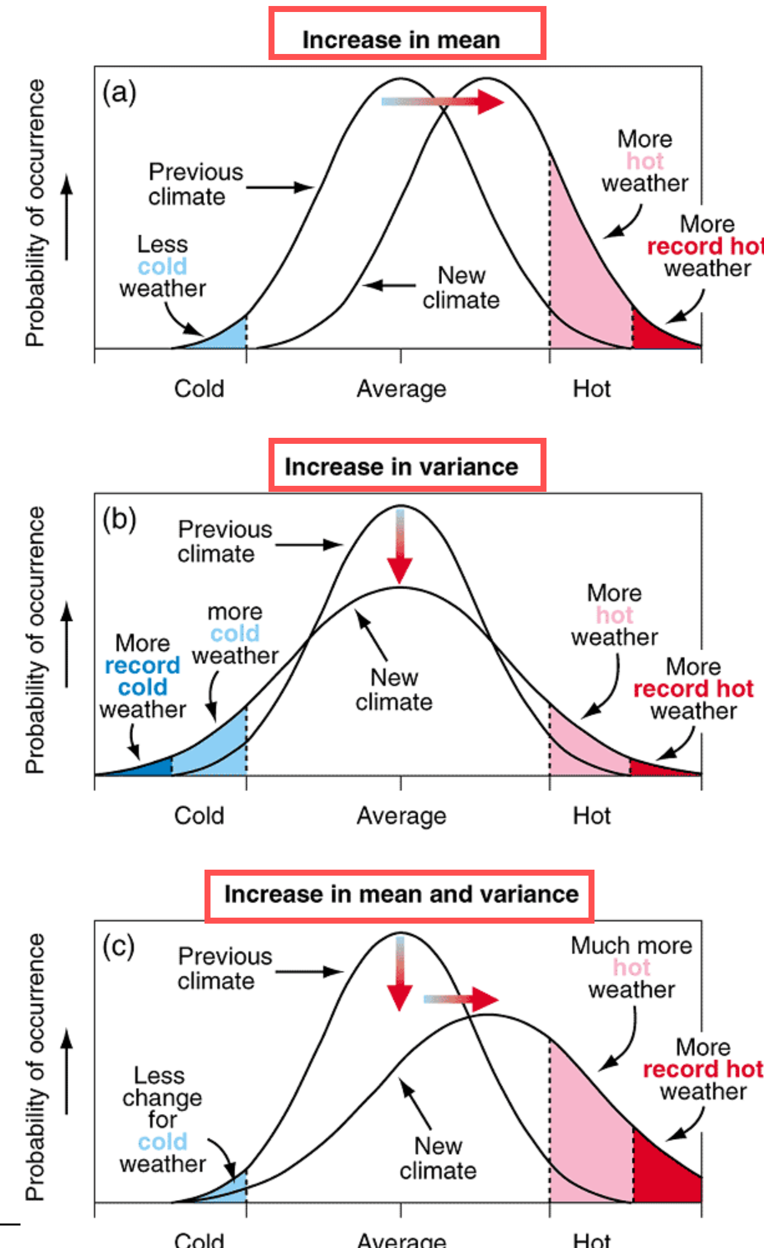
UCLA Studies: Evaluating how future climate variability and land cover change (fire) will affect water resources in So. California

Uncertainty in Future Climate



GCM change in temperature simulations from IPCC AR4 Synthesis Report (2007)

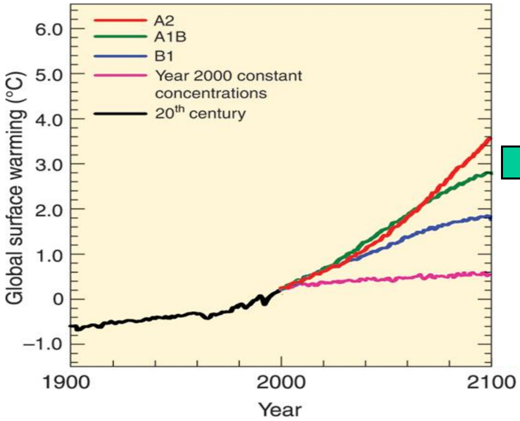
What shifts will we see?



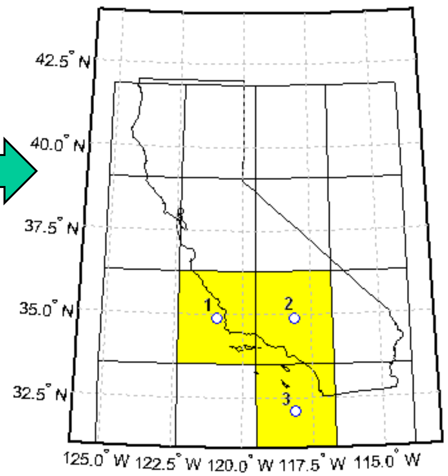
Biennial CAT Report (2009)

Traditional Models and Assessment

Emission Scenarios



General Circulation Models (GCMs)

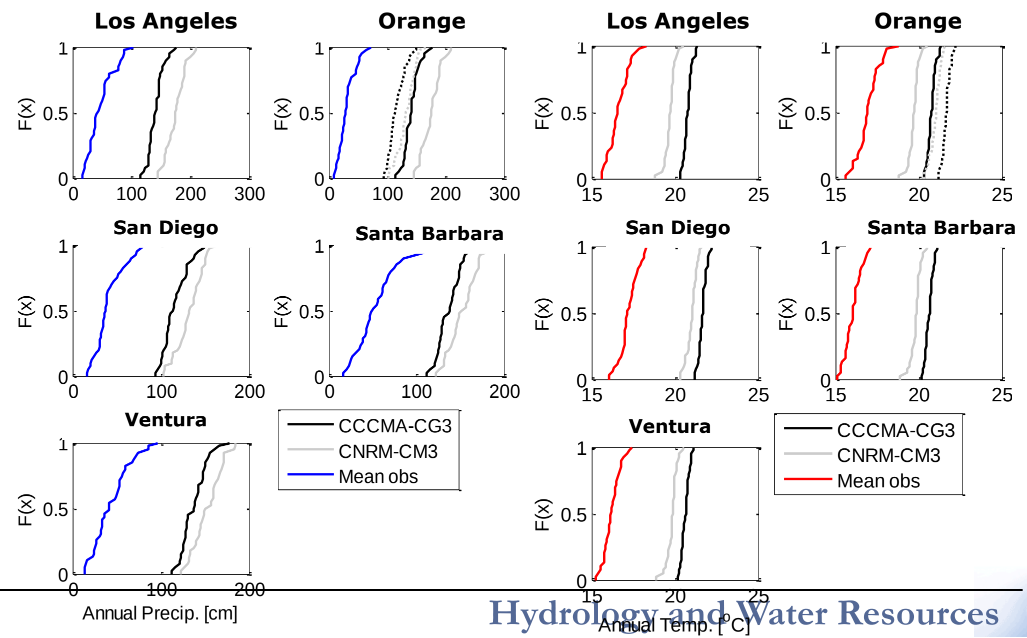


GCMs large region
Resolution: 2.5° – 10°

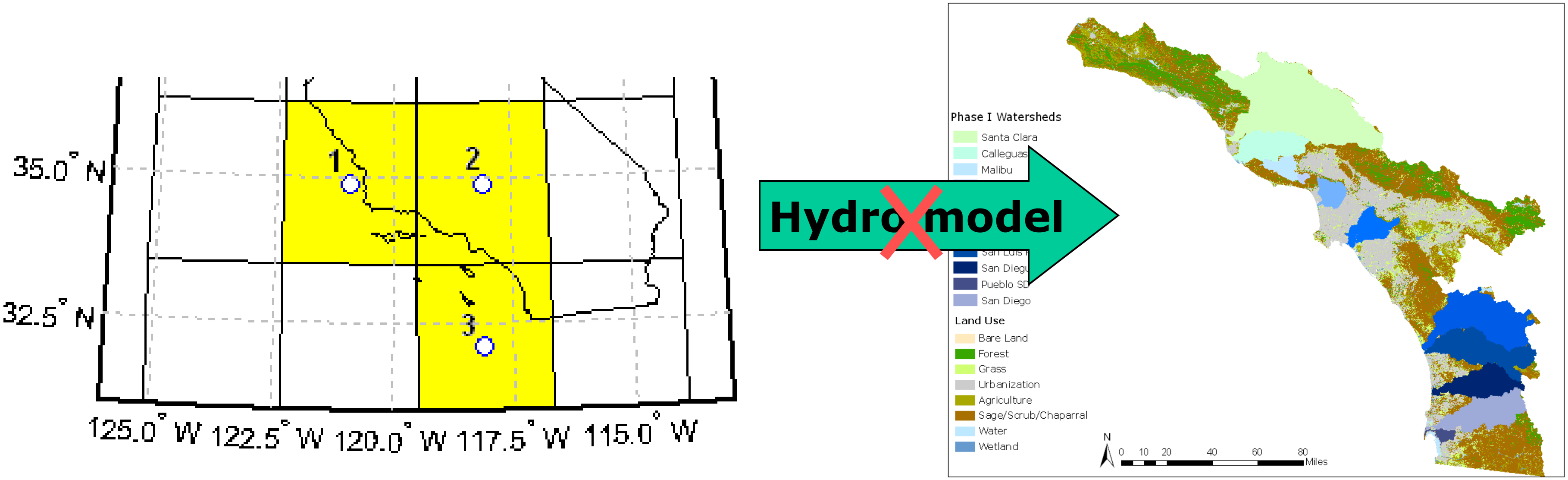
Fail to capture regional variability necessary for **watershed-scale** analysis

Downscaling

Scale disconnect for regional analysis and decision-making



Uncertainty in watershed evaluation?



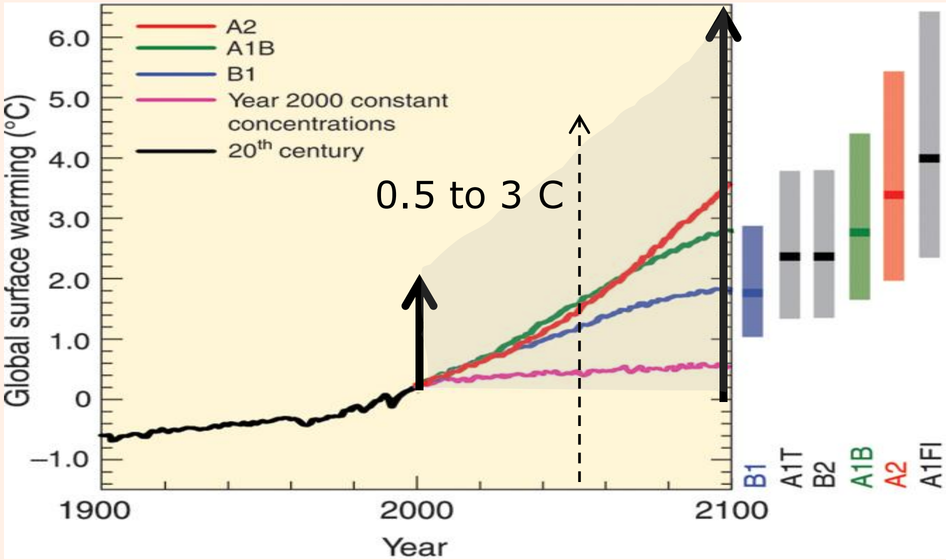
Problem:

Unable to directly use GCM simulations for hydrologic simulations

Solutions:

Dynamic (Regional Climate Models (RCM)) or **Statistical Downscaling** or using **Historical Data** to predict future observations (add noise and trends)

Create future scenarios from historical observations



GCM change in temperature simulations from IPCC AR4 Synthesis Report (2007)

Temperature

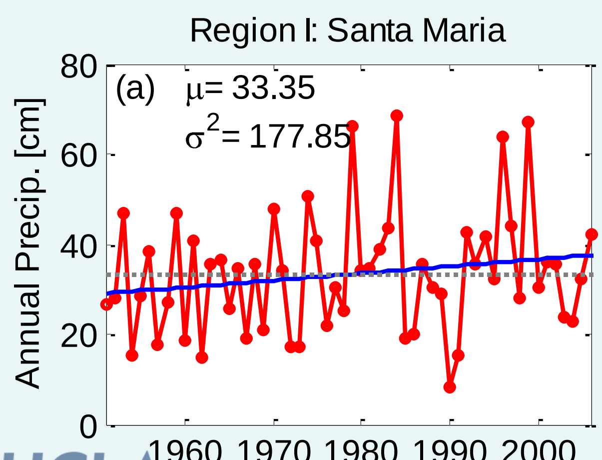
Project linear increase

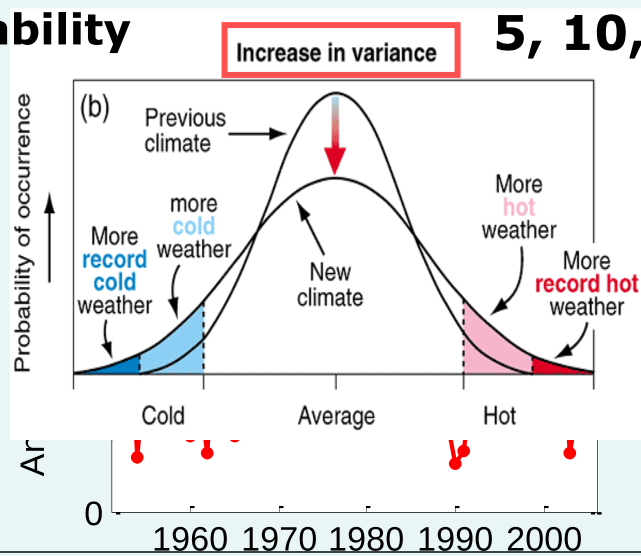
- 0.5 to 2 C in California within the first 30 years of the 21st century

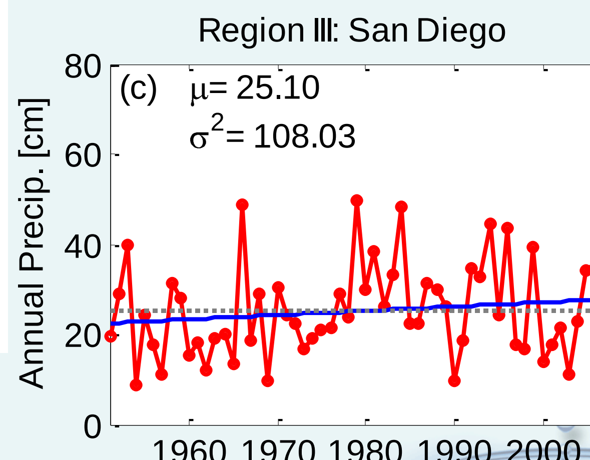
(California Action Team, 2009)

Precipitation – add variability

5, 10, 25, 50%







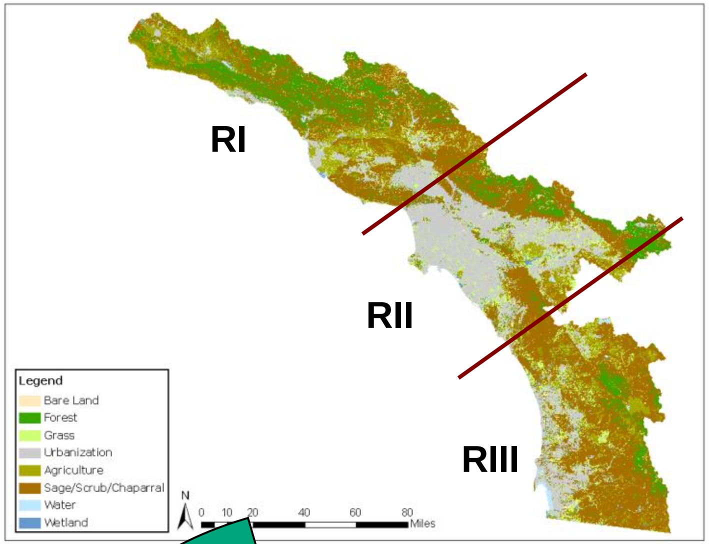
Assessment for Regional Hydrologic Change

1. Construct Regional Archetypal Systems

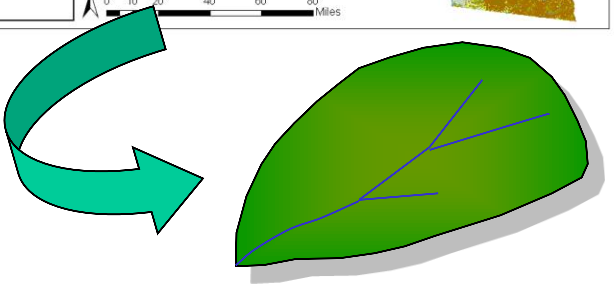
    Vegetated (Ventura/SB Cty))

    Urban (Los Angeles Cty)

    Mixed (San Diego Cty)

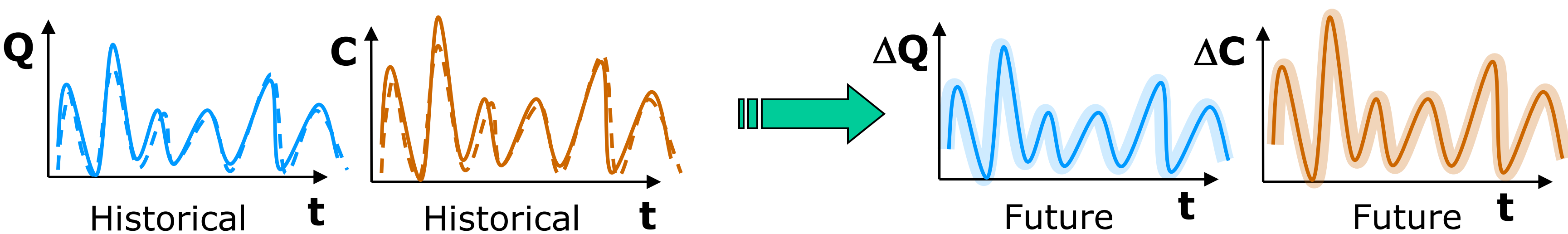


2. Run scenarios through hydrologic model (EPA HSPF)



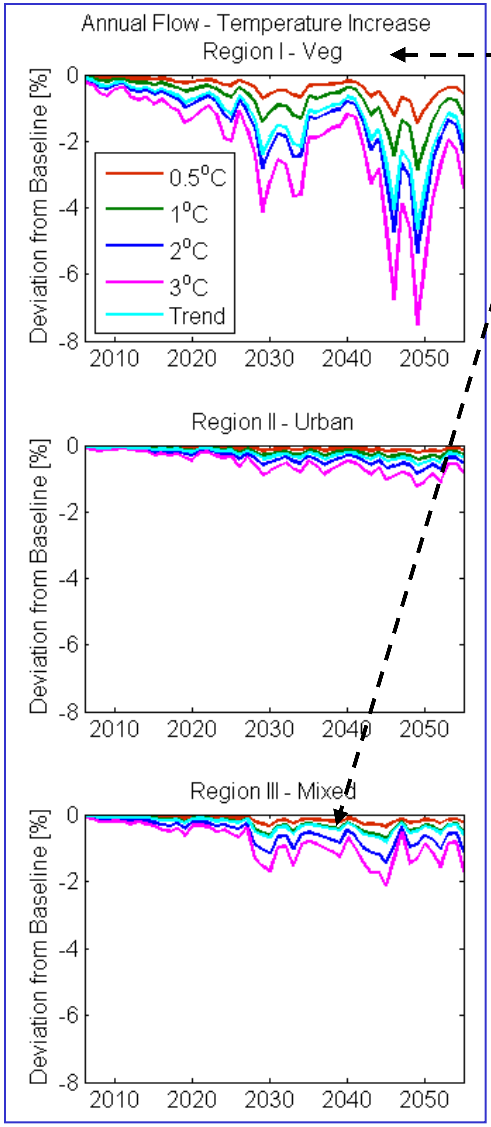
3. Simulate historical streamflow/sediment and validate

4. Predict future hydrologic response



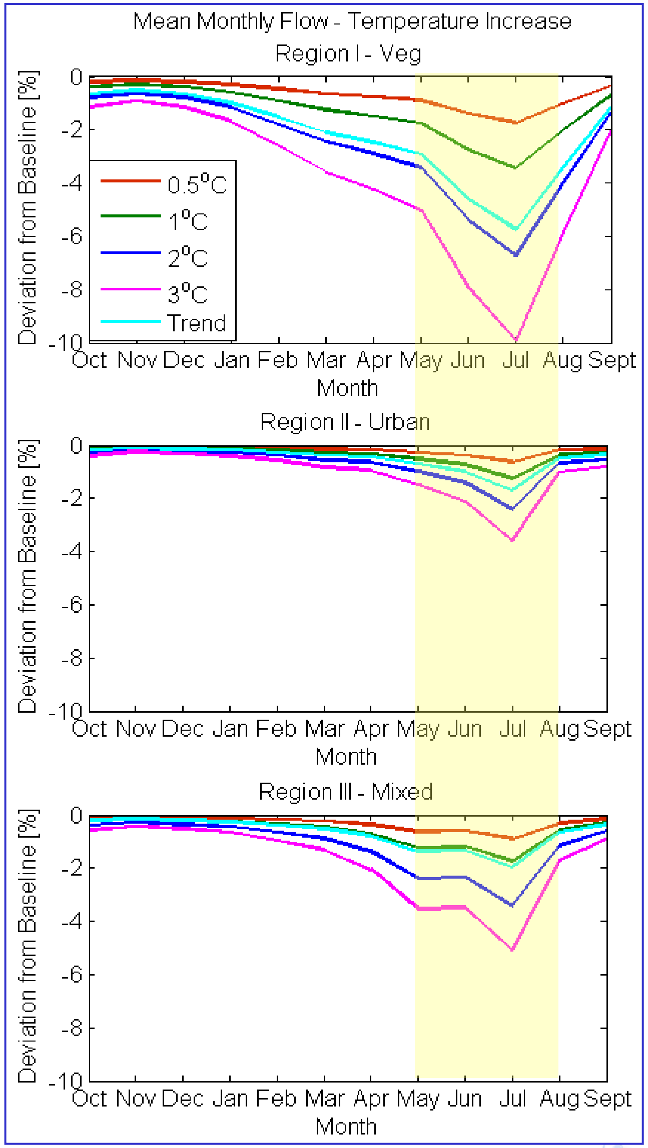
Lopez et al 2011, in review

Hydrologic Response: Temp Increase alone



- **Decrease in annual flow (increase in ET)**
- **More evident in vegetated & mixed systems, especially during dry periods (summer)**

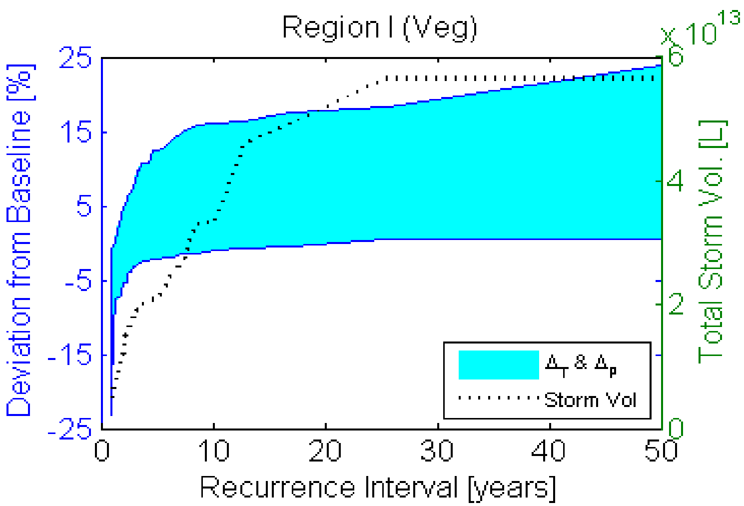
Region	Peak Flow Reduction	
RI	0.37 cm	7.51%
RII	1.72 cm	1.25%
RIII	1.53 cm	2.13%

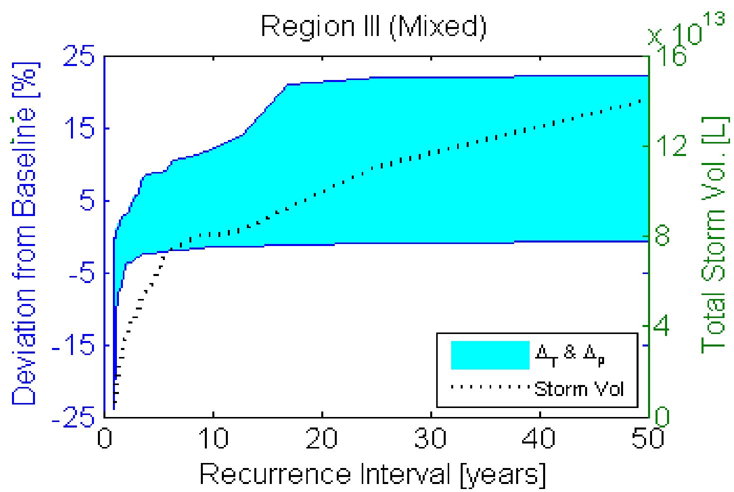


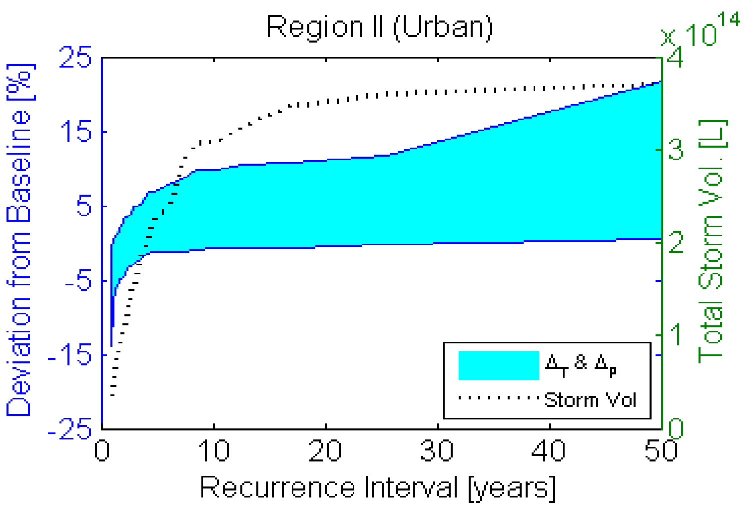
Lopez et al 2011, in review

Hydrologic Response: Precip Var & Temp Increase

Recurrence interval of total storm volume







Uncertainty bounds widen for all systems

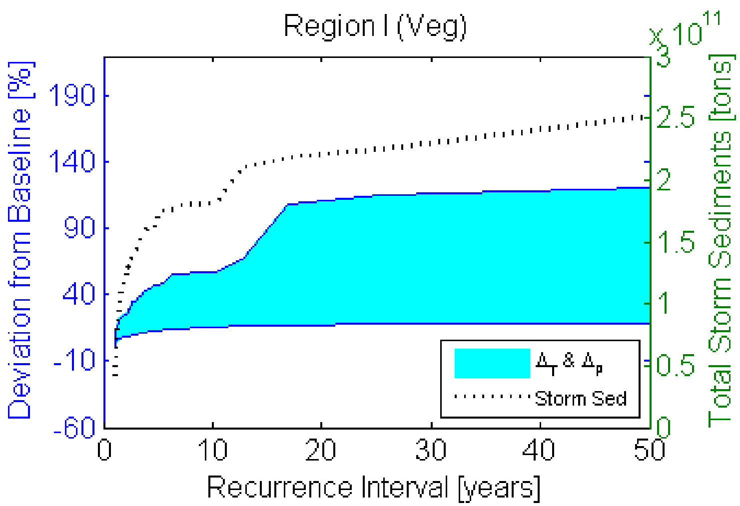
Enhanced response in vegetated and mixed

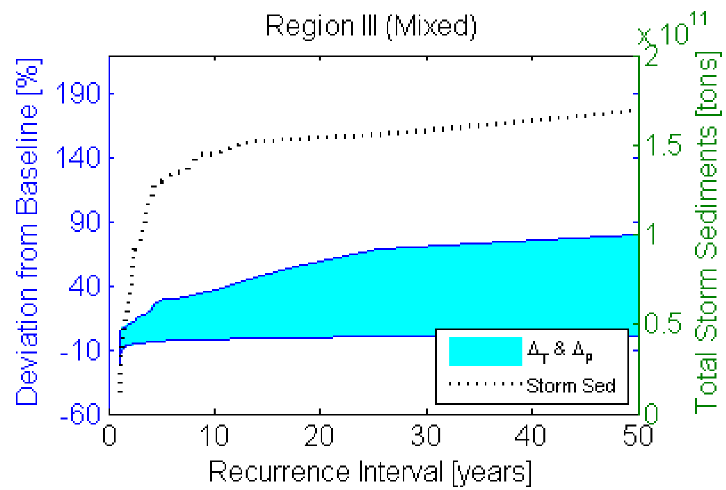
Larger deviations in higher flood events

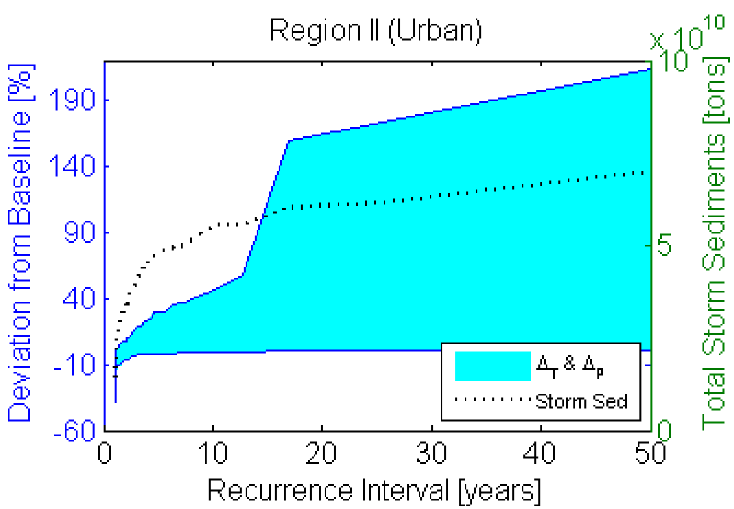
Lopez et al 2011, *in review*

Sediment Response: Precip Variability & Temp Increase

Recurrence interval of total storm sediments



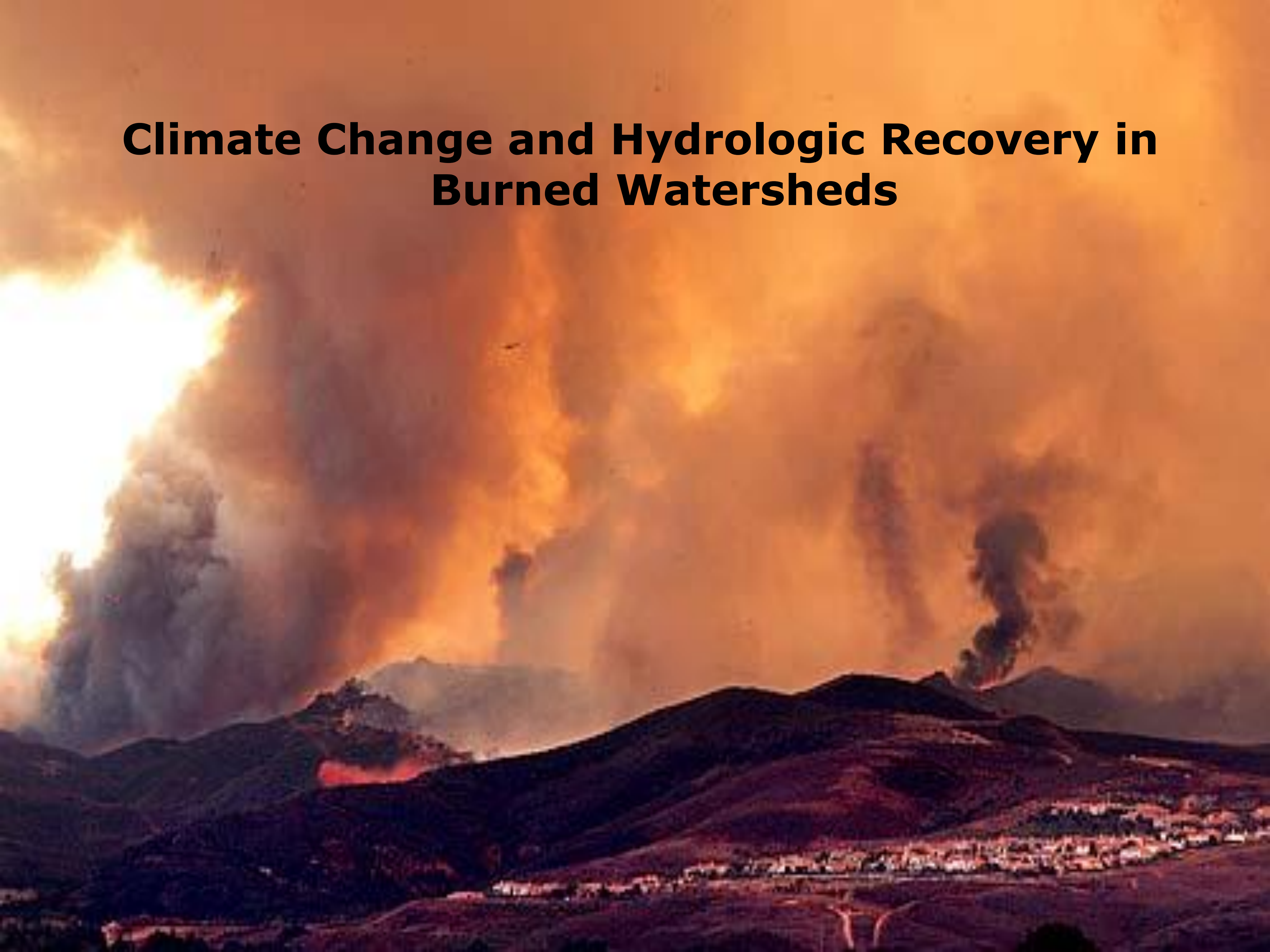




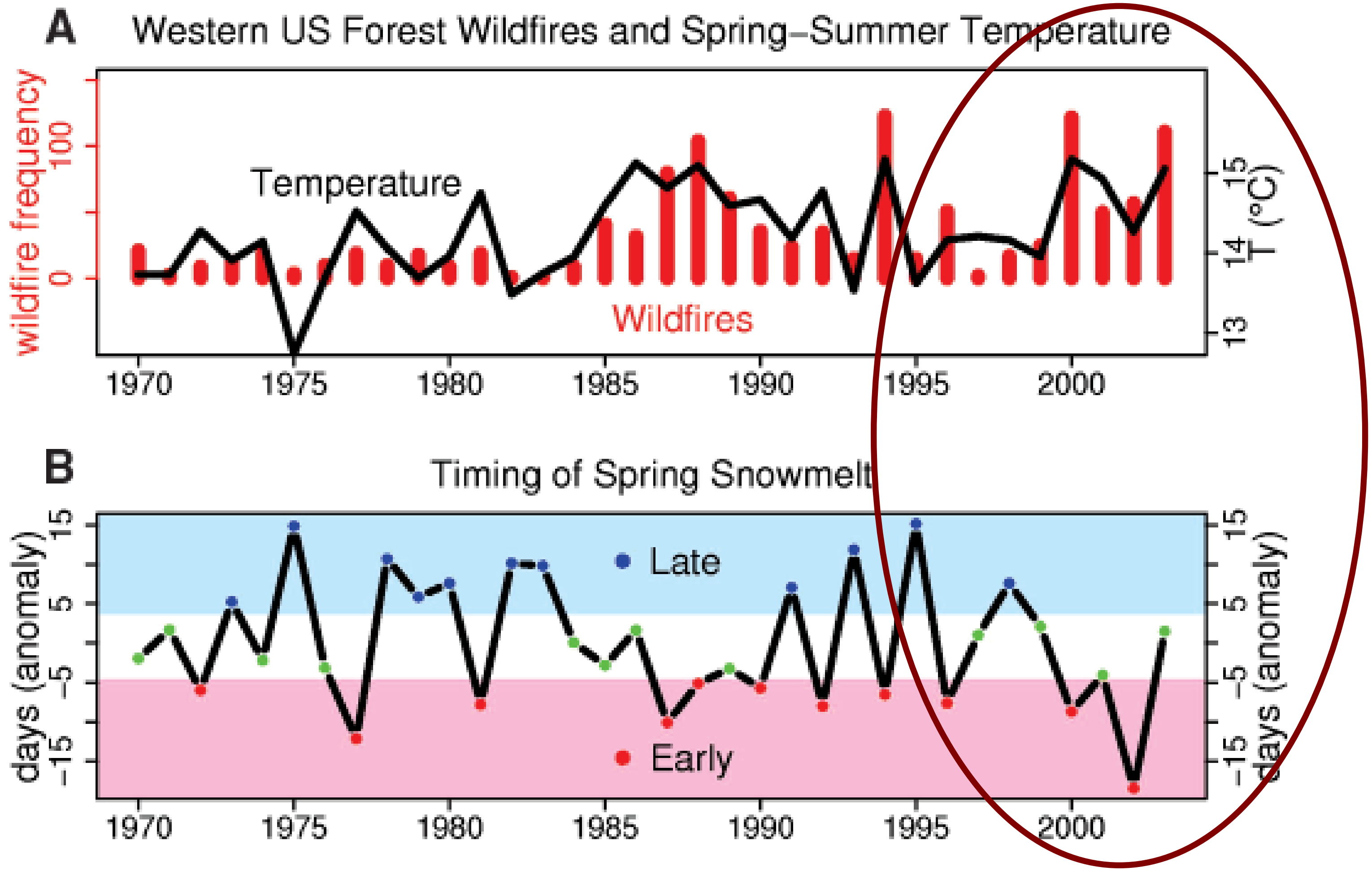
Enhanced sediment wash-off during larger storms in urban systems

Lopez et al 2011, *in review*

Climate Change and Hydrologic Recovery in Burned Watersheds



Increasing Wildfire Frequency

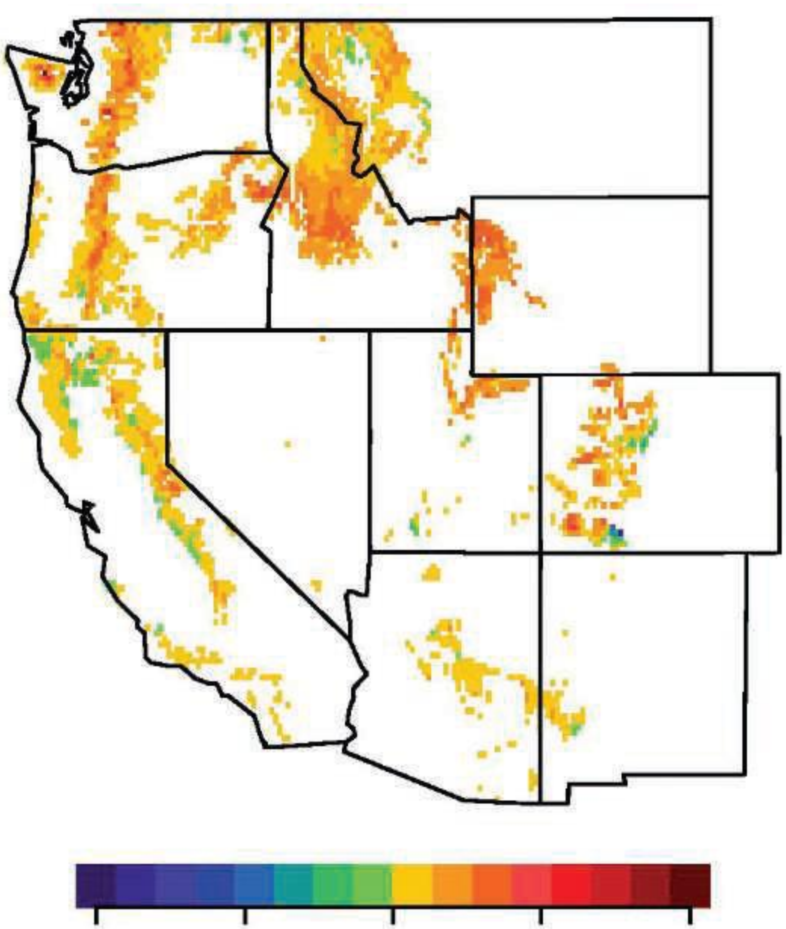


Spring soil moisture deficit expected to play a key role in future fire frequency

CEC, 2007

Less moisture – more wildfires…

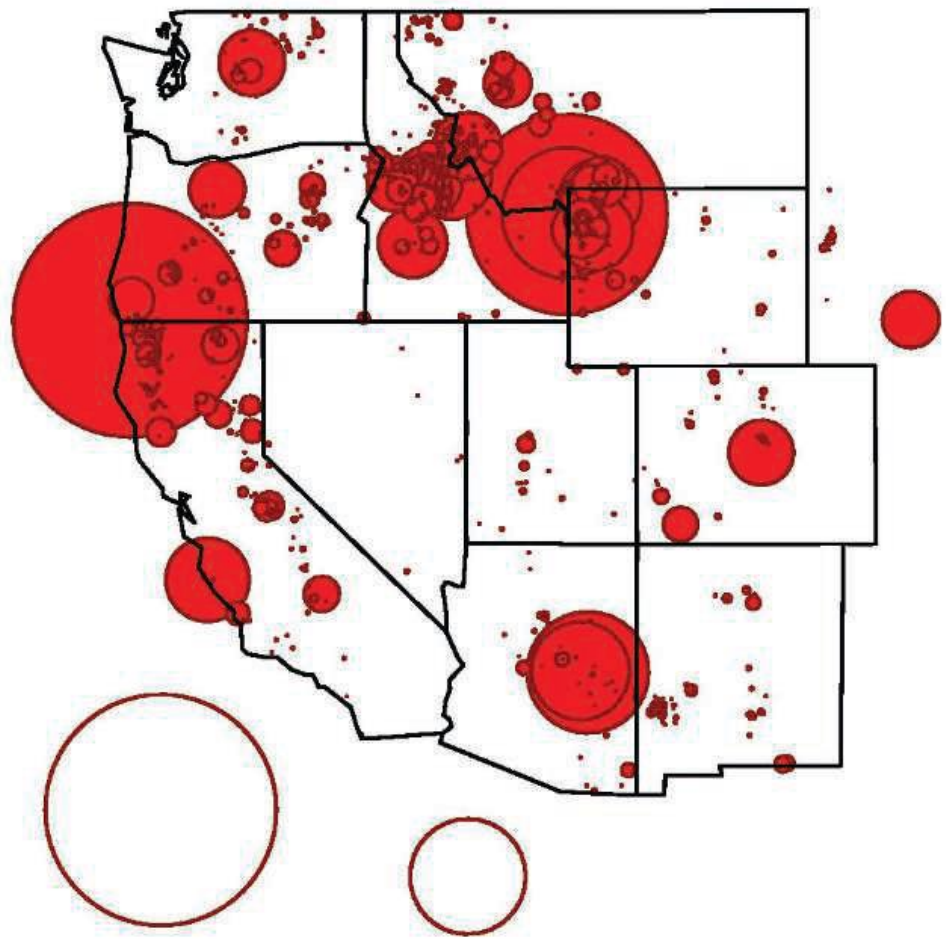
1970 to 2003 Spring and Summer moisture availability



–90 –45 0 45 90

Percentage charge in average moisture deficit

1970 to 2003 Large Fires (> 1000 ha)



200,000 ha **100,000 ha**

CEC, 2007

"The risk of large wildfires in California could increase by as much as 55 percent" CEC, 2007

Recent Wildfires in Southern California

Regional Wildfires

2003
750,000 acres southern California
24 fatalities, numerous homes

2005
24,000 acres northwestern LA County

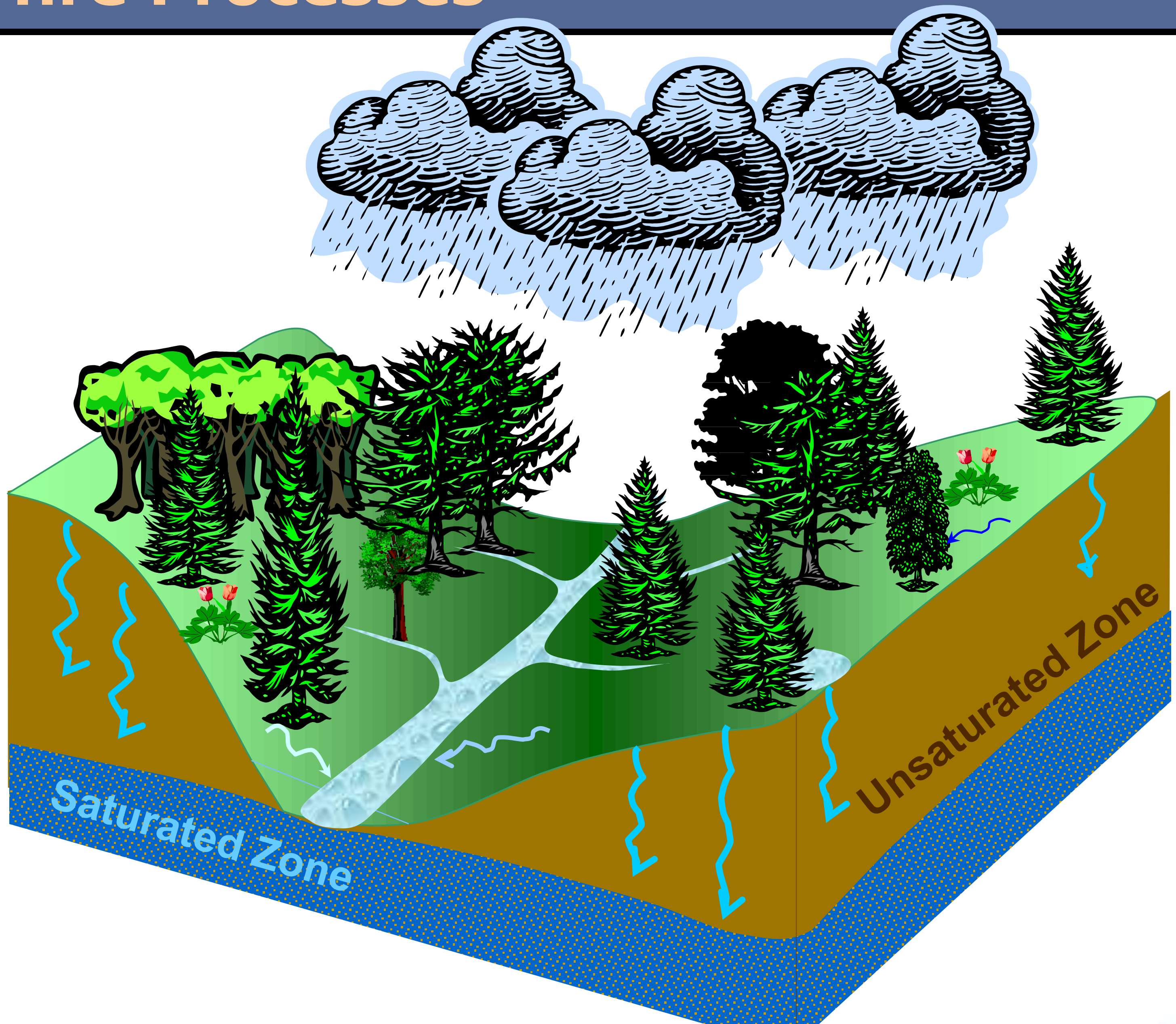
2006
160,000 acres LA and Ventura Counties (Day Fire – 5th largest in CA history)

2007
240,000 acres Santa Barbara County (Zaca Fire - largest in CA history)
490,000 acres, **14 fatalities, >1500 homes** in Regional Fires

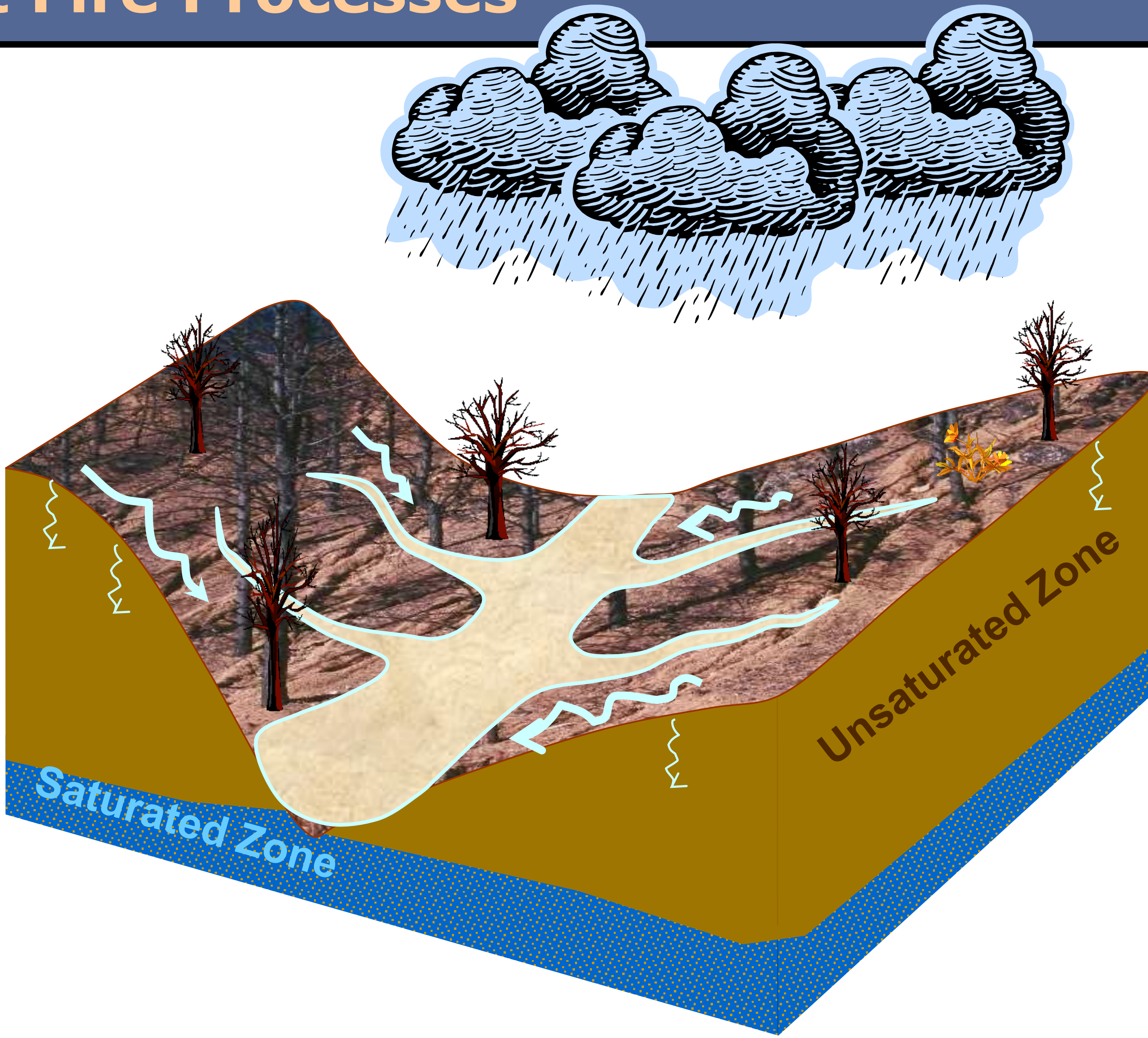
2009
160,000 acres, 2 deaths, >80 homes - Station Fire

October, 2003 (NASA)

Pre-fire Processes



Post Fire Processes



Wildfire Impacts

Physical/chemical changes

Acute loss of vegetation, decreased soil cohesion, ash layer deposition, hydrophobic layer formation.

Hydrologic consequences

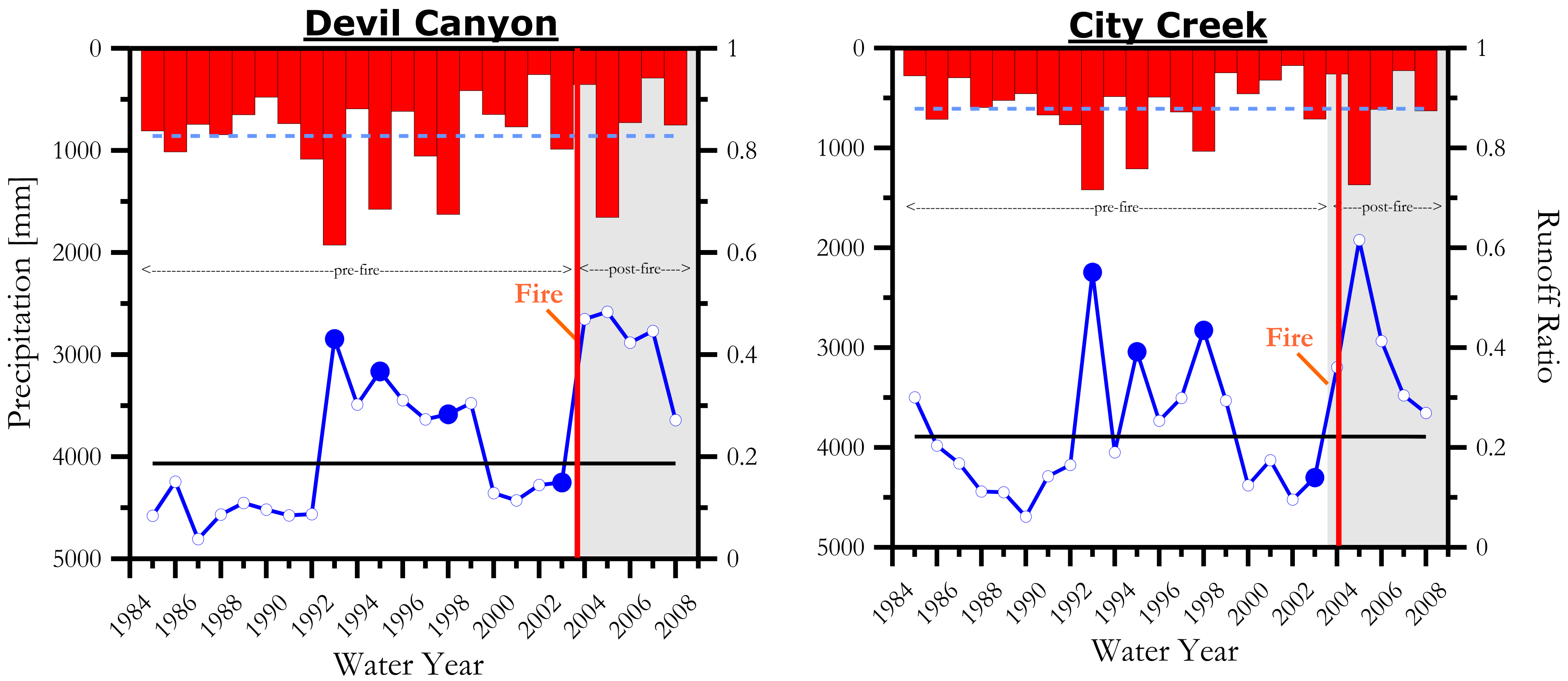
Decreased: infiltration, ET demand, water quality

Increased: erosion, overland flow, flooding, sediment laden and debris flow occurrence, dry season flow.

Why??? Hydrophobicity and Ash Deposition

Long-term hydrologic recovery

2003 Old Fire in San Bernardino Mts.



How long does altered flow regime last??
CLIMATE DEPENDENT!!

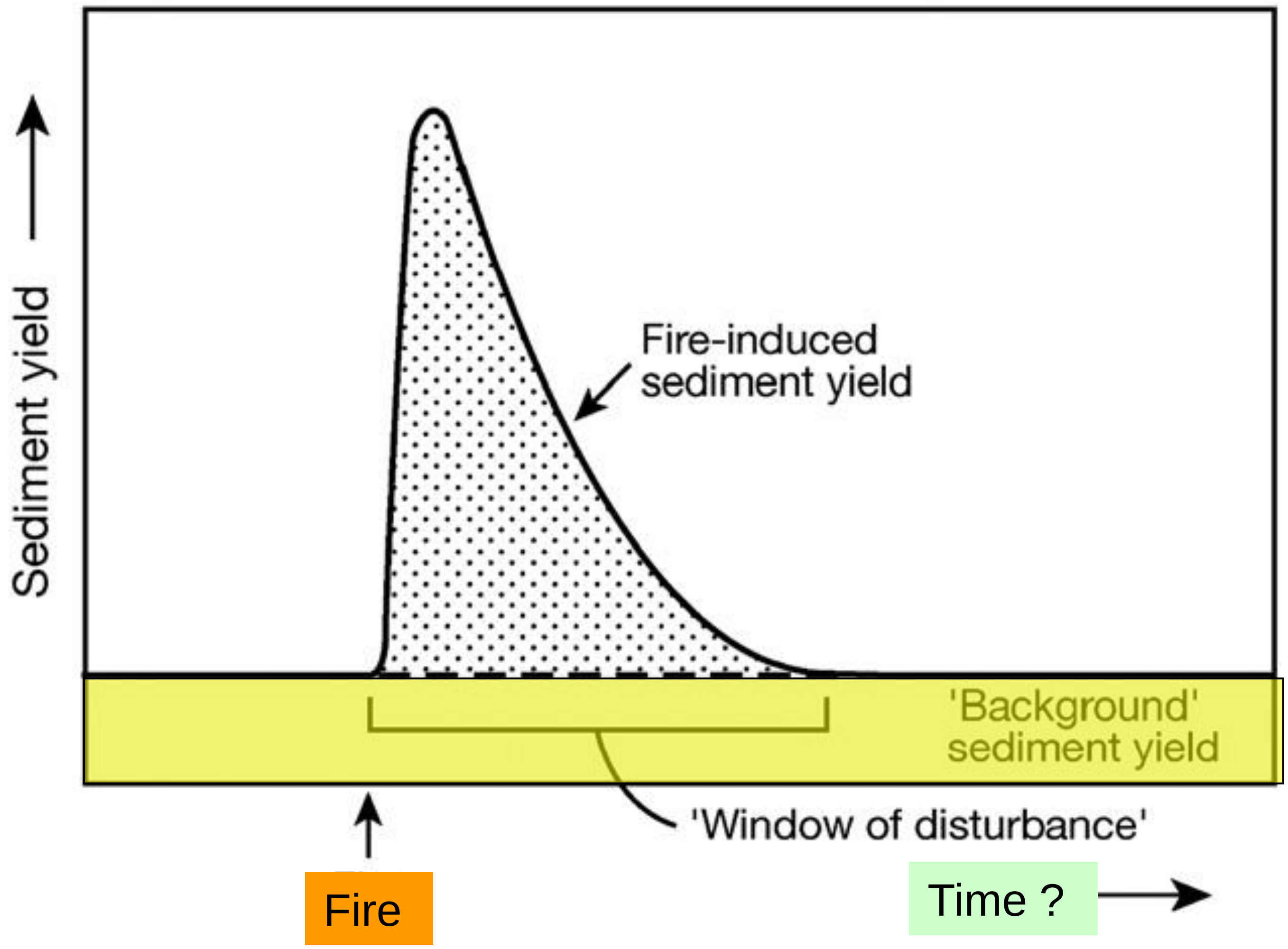
Kinoshita and Hogue, 2011

Post-fire Sediment and Debris Flows

Post-fire Debris and Sediment Flows
Carry nutrients, metals, other contaminants (atmospherically-deposited)

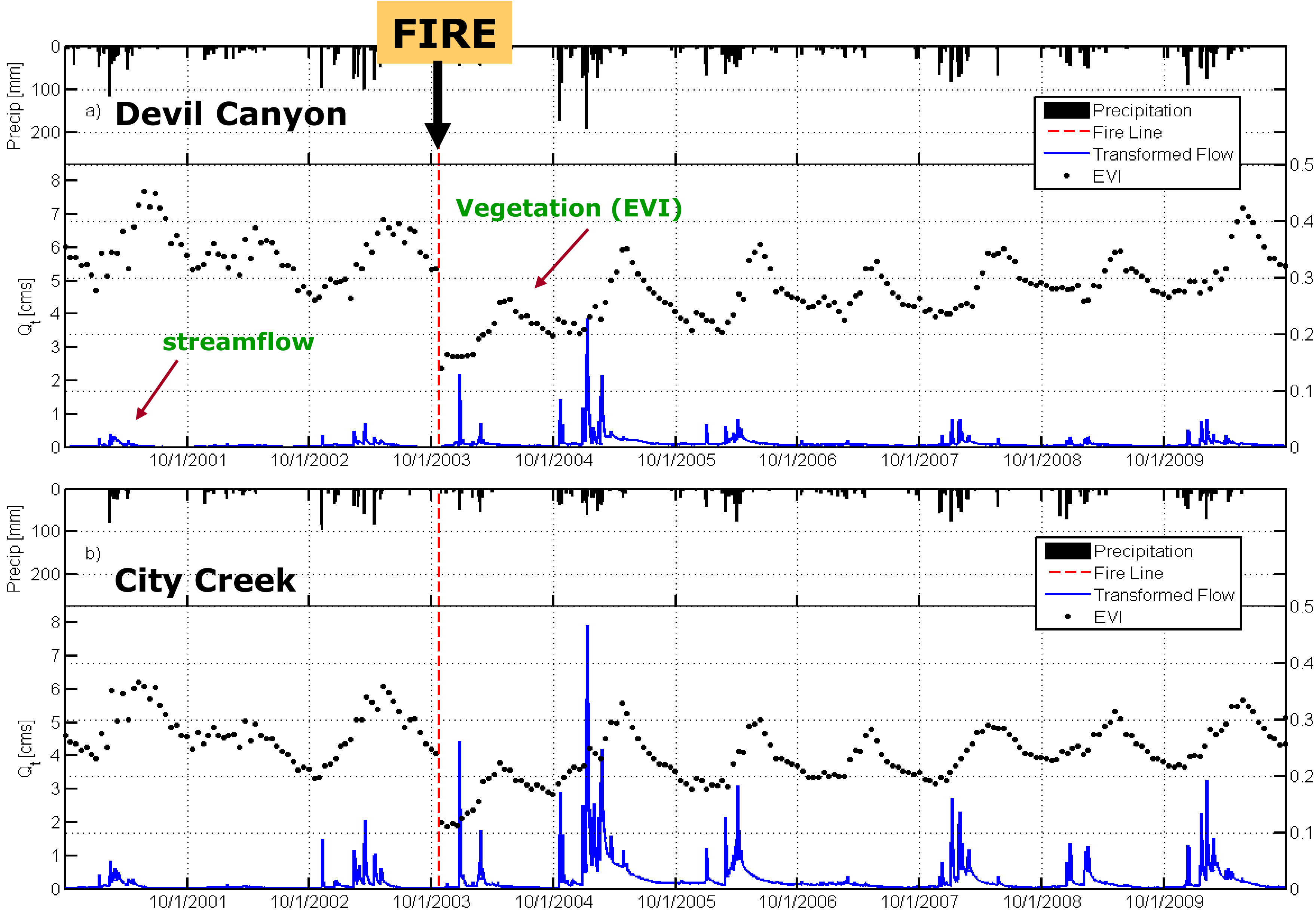
Photos courtesy of Paul Dolter, EVWD

Fire and Sediment Disturbance



Shakesby, 2011

Coupled Hydrologic and Vegetation Recovery



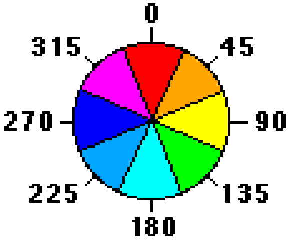
Kinoshita and Hogue, 2011

Factors controlling watershed recovery

- **Pre-fire vegetation**
- **Burn severity**
- **Slope/aspect**
- **Post-fire climatology (precipitation, temp)**
- **Soil type**
- **Others…**

Aspect (Wittenberg et al., 2007)

North (315 -45)
East (45 -135)
South (135 -225)
West (225 -315)



Burn Severity

- MODIS (MOD13Q1) bands #2 & 7 (NIR,MIR)
- Estimate Normalized burn Ratio (NBR)

NBR=(Band 2 - Band7)/(Band 2 + Band 7)

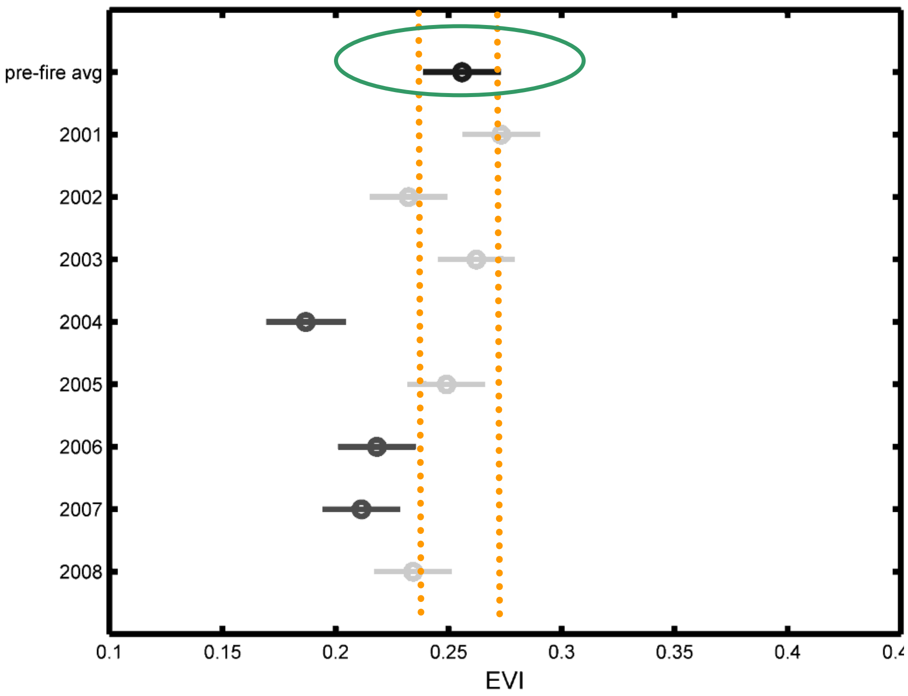
- Calculate pre- and post-fire NBR
- Calculate differenced (delta) NBR

$$\mathbf{dNBR=NBR_{prefire} - NBR_{postfire}}$$

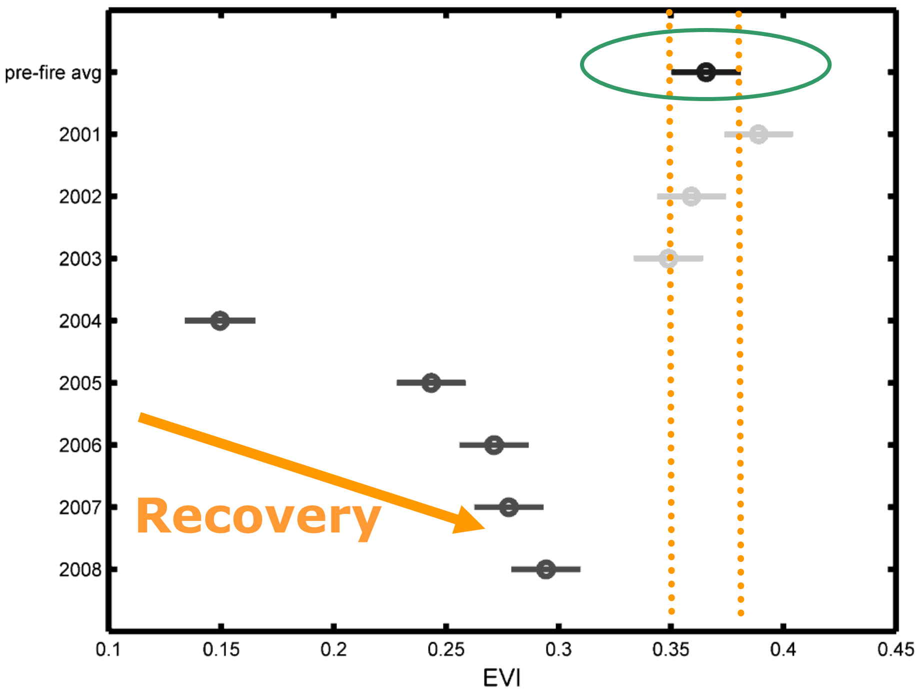
Recovery relative to study determinants

burn severity, aspect, post-fire climate!!

South Low Burn



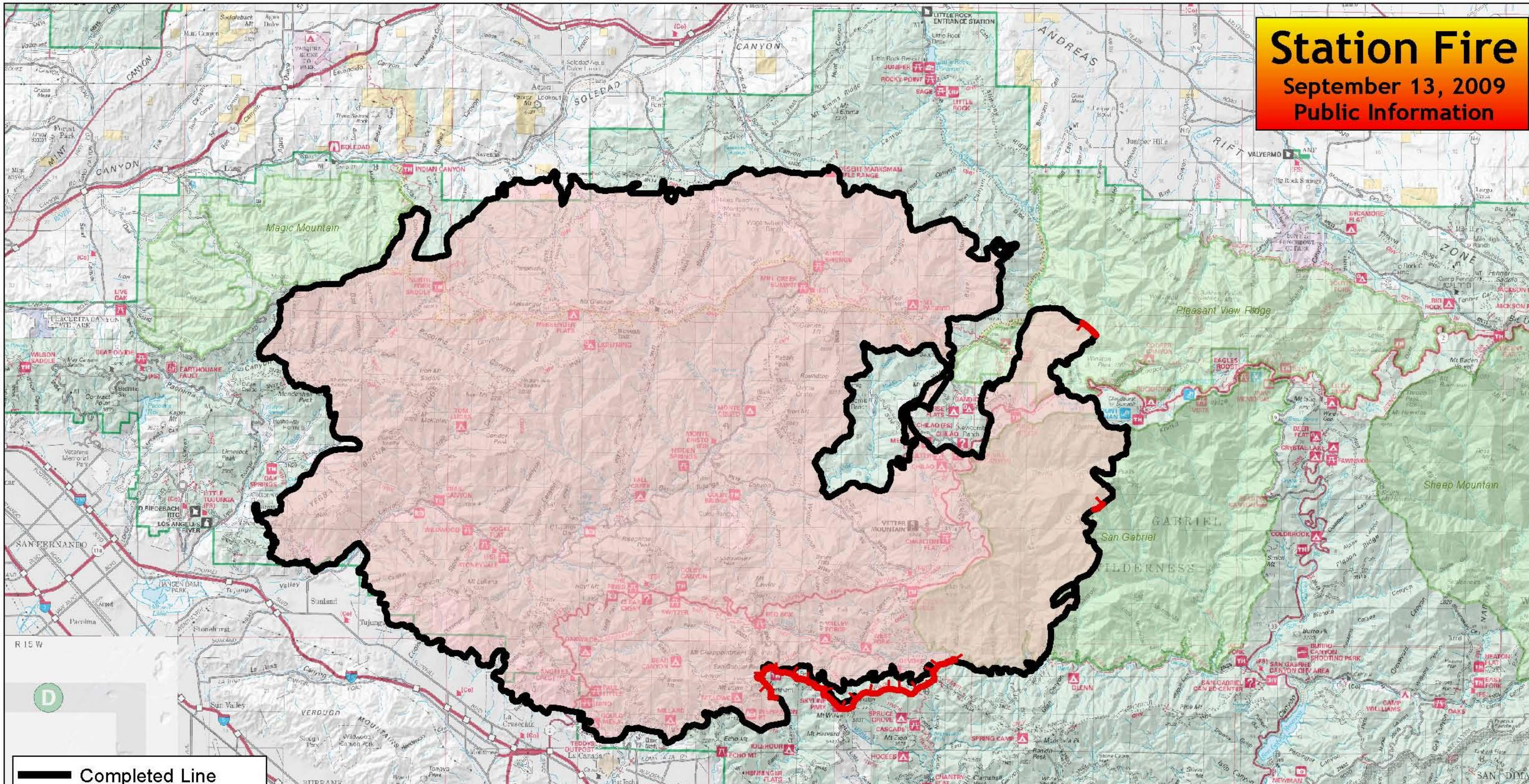
South High Burn



(Kinoshita and Hogue, 2011)

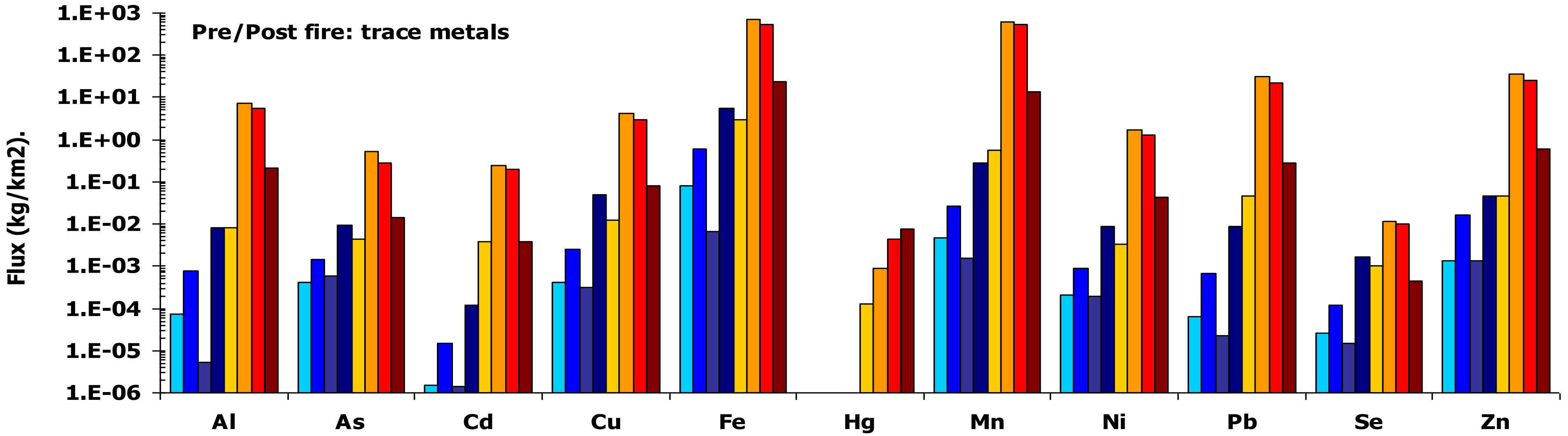
Urban-wildland Fires

Station Fire (2009)- Largest in Los Angeles County History



Southern California's urban fringe watersheds experience extremely high atmospheric deposition of urban contaminants and corresponding pollutant loads in stream systems **(Riggan et al. 1985; Herpe and Troch 2000; Butturini et al. 2003; Meixner and Fenn 2004; Barco et al., 2008).**

Pre/Post-Fire Mass Loading (Metals) in the Arroyo Seco



- Sediment flux (not shown) increased 100 fold after fire
- Post-fire trace metal flux significantly enhanced, > 3 orders of magnitude increases observed (Cd, Mn, Pb)
- Post-fire metal flux on the order of that observed draining mining sites, industrial areas, & highways
- Largest post-fire storm delivered 1.2t Lead, 1.5t Zinc, 70kg Nickel, 22kg Arsenic, and 10kg Cadmium

Take Home Message (Climate-Hydrology-Fire)

Hydrologic Response and Climate Change:

- **Increasing temperature – reduced runoff/recharge in So. Cal. region**
  - **- Increasing aridity! Vegetated and mixed systems more vulnerable!**
- **Increasing temp and ppt variability – storm response highly variable**
  - **- Increased sediment flux in urban systems**
  - **- More uncertainty in discharge / flood events**

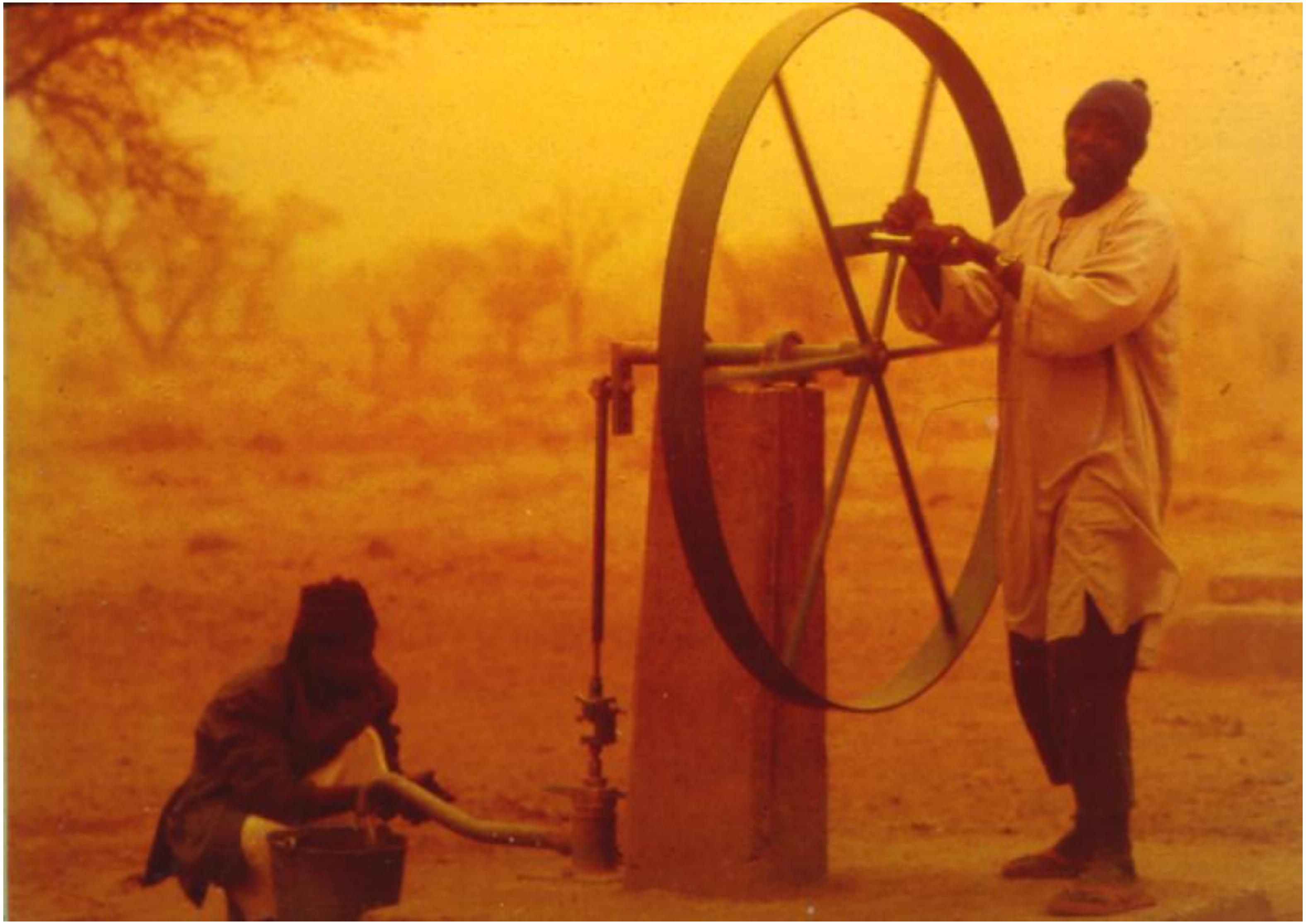
    (infrastructure challenges)

Post-fire Recovery and Climate Change (few studies in this area):

- **Precipitation extremes (variability) impact**
  - **- Pollutant loads**
  - **- Flooding and debris flows**
- **Recovery patterns (coupled vegetation-hydrologic response) are highly dependent on various determinants including climate variability**
- **Recovery prediction will be difficulty as models required to operate outside of normal constraints**

→ Need for longer-term coupled hydrologic-vegetation studies

Questions??



When the wells run dry, we know the worth of water

Benjamin Franklin [1746]

Select publications (Climate-Hydrology-Fire Recovery):

- Kiparsky M and Gleick PH. 2003. Climate Change and California Water Resources: A Survey and Summary of the Literature. *Pacific Institute for Studies in Development*, *Environment, and Security*. Oakland, CA.
- Maurer EP, Hidalgo HG, Das T, Dettinger MD, Cayan, DR. 2010. The utility of daily large-scale climate data in the assessment of climate change impacts on daily streamflow in California. *Hydrology and Earth System Sciences* 14(6): 1125-1138. DOI: 10.5194/hess-14-1125-2010
- Hidalgo HG, Das T, Dettinger MD, Cayan DR, Pierce DW, Barnett TP, Bala G, Mirin A, Wood AW, Bonfils C, Santer BD and Nozawa T. 2009. Detection and Attribution of Streamflow Timing Changes to Climate Change in the Western United States. *Journal of Climate* 22(13): 3838-3855. DOI: 10.1175/2009JCLI2470.1
- Lopez, S.R, T.S. Hogue, and E. Stein, 2011. Evaluating Regional Climate Change Impacts on Streamflow and Sediment Flux Using Archetypcal Watersheds, *Int Journal of Climate (in review)*
- Cydzik, K. and T.S. Hogue, 2009: Modeling Post-fire Response and Recovery using the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS), *Journal of the American Water Resources Association,* 45(3):702-714.
- Keeley , J.E., Fotheringham, C.J., and Baer-Keeley M., 2005. Determinants of Postfire Recovery and Succession in Mediterranean-Climate Shrublands of California. *Ecological Applications* 15(5): 1515-1534.
- Keeley, J.E., Brennana, T., and Pfaff, A.H., 2008. Fire Severity and Ecosystem Responses Following Crown Fires in California Shrublands. *Ecological Applications*, 18(6): 1530-1546
- Kinoshita, A.M, and T.S. Hogue, 2011. Spatial and Temporal Controls on Post-fire Hydrologic Recovery in Southern California Watersheds*, Catena (in review)*
- Running, 2006: Is Global Warming Causing More, Larger Wildfires? *Science,* 313, 18 August, 2006
- Service, R., 2004: As the West Goes Dry, *Science*, (303), 1124-1127
- Westerling A.L., Hidalgo H.G., Cyan D.R., Swetnam T.W., 2006. Warming and earlier spring increase Western U.S. wildfire activity. *Science*, 313: 940-943.
- Wittenberg, L. and Inbar, M., 2009: The Role of Fire Disturbance on Runoff and Erosion Processes – a Long-Term Approach, Mt. Carmel Case Study, Israel. *Geographical Research* 47(1): 46-56.